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AUTHORITY

USABSRL ltr, 31 Jan 1969

Technical Research Note 194

RELATION OF CERTITUDE JUDGMENTS TO CHARACTERISTICS OF UPDATED SYMBOLIC INFORMATION

Robert S. Andrews, Frank L. Vicino,
and Seymour Ringel

U. S. Army
Behavioral Science Research Laboratory

April 1968

Technical Research Note 194

AD

RELATION OF CERTITUDE JUDGMENTS TO CHARACTERISTICS OF UPDATED SYMBOLIC INFORMATION

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Washington, D. C. 20315

April 1968

Army Project Number
2J024701A723

Command Systems e-11

Wash., D.C. 20315

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FOREWORD

Technological advancements have led to increased speed, mobility, and destructive power of military operations. To permit commanders to make tactical decisions consistent with rapid change and succession of events, information on military operations must be processed and used more effectively than ever before. To meet this need, the Army is developing automated systems for receipt, processing, storage, retrieval, and display of different types and vast amounts of military data. There is a concomitant requirement for research to determine how human abilities can be utilized to enable the command information processing systems to function with maximum effectiveness.

One objective of the COMMAND SYSTEMS Task is to provide research information by which decision making and information assimilation from displays may be facilitated. To this end, studies are conducted on such information presentation factors as amount, density, format, color coding, specificity-generality, alpha-numeric vs symbolic displays, rate and degree of updating, probability data and certitude, individual and group displays, and the relative utility of different sensory and display modalities. The present publication reports on a portion of Subtask e, "Effective aids in the decision process," and explores relationships between the accuracy with which information is assimilated and the certitude that the information assimilated is correct.

The entire research task is responsive to requirements of RDT&E Project 2J024701A-723, "Human Performance in Military Systems," FY 1968 Work Program, and to special requirements of the Combat Developments Command and the Army Materiel Command.

J. E. UHLANER, Director
U. S. Army Behavioral Science
Research Laboratory

RELATION OF CERTITUDE JUDGMENTS TO CHARACTERISTICS OF UPDATED SYMBOLIC INFORMATION

BRIEF

Requirement:

In the Army's command information processing systems, updating of situational data adds to the difficulty of information assimilation and may affect confidence in accuracy of information and, consequently, the quality of decisions made on the basis of the information. The purpose of the present research was to explore the effects of type and number of updates, total amount of information presented, and selected conspicuity coding techniques on confidence and the relationship of confidence to accuracy of information assimilation.

Procedure:

Forty-eight subjects were presented successive pairs of slides. The first slide of a pair contained 12, 18, or 24 military flag symbols randomly positioned on a map. The second slide was identical to the first except that 2, 4, or 6 symbols had been added, removed, or repositioned. After the subjects had successively viewed both slides of a pair, the second slide was removed. Subjects then indicated on a paper print of the first slide all updates they had noted in the second slide. Performance was measured in terms of accuracy of assimilation (a percentage score) and confidence in that accuracy (ranging from 1-absolutely uncertain, to 8-absolutely certain). The research design was replicated over three enhancement techniques--single cue coding, double cue coding,and hard copy, as well as with no enhancement.

Findings:

Increasing either amount of information presented or amount of updating resulted in a decline in both mean accuracy and mean certitude, the rate varying widely over the different enhancement techniques and over types of update.

Mean certitude paralleled mean accuracy reasonably well, but the accuracy-certitude correspondence did not hold for individual performance scores. Over all conditions, only 38 percent of the certitude variance could be accounted for by accuracy variance.

The more effective the enhancement technique, the higher the certitude-accuracy relationship. With the best enhancement technique (double-cue coding), 64 percent of the certitude variance could be accounted for by accuracy variance, with the poorest (hard copy), only 30 percent.

There was evidence of both over-certitude and under-certitude, over-certitude tending to increase with the less effective enhancement techniques.

Utilization of Findings:

Findings suggest need to improve agreement between a man's performance in information assimilation and his estimate of that performance.

In the absence of specific information to the contrary, it should be assumed that most techniques which aid assimilation will also improve certitude estimates though the effect may vary with the technique.

Reliance on group estimates should be encouraged, at least until techniques for improving estimation are devised.

Determination of the role of certitude in the timeliness and appropriateness of decisions should be a prime research objective. To this end, certitude should be measured in the same metric as accuracy (percent).

RELATION OF CERTITUDE JUDGMENTS TO CHARACTERISTICS OF UPDATED SYMBOLIC INFORMATION

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OBJECTIVES

The Command Systems Task of the U. S. Army Behavioral Science Research Laboratory is conducting a series of projects in which a variety of display variables are systematically investigated in terms of their effects on information assimilation and decision making in a command and control setting. A concomitant of information assimilation is the confidence or feeling of certitude the viewer has in the accuracy of his assimilation. To the extent that feelings of confidence or certitude appropriately reflect the assimilation performance upon which they are presumably based, decision behavior could be enhanced. It is therefore of interest to know more about the certitude-accuracy relationship as a function of various display parameters and to determine the degree to which accuracy and certitude may be differentially affected.

In an earlier study[1] the number of symbols removed in an updating (2 through 8) had negligible effect on accuracy of assimilation, but the greater number of changes did result in an appreciable decrement in certitude. The present experiment was an attempt to determine whether the findings for updating generalize beyond the specific circumstances of the earlier study and whether related variables show similar effects.

The specific objectives of the present study were:

1. To determine whether accuracy of information assimilation from displays and judgments of certitude are similarly affected by (1) amount of information presented, (2) type of updating change, and (3) extent of updating change.

2. To determine the extent to which the accuracy-certitude relationship varies with techniques to enhance the conspicuity of updates--updated hardcopy for reference, single-cue coding, double-cue coding.

METHOD

Experimental Design

The independent variables investigated were total number of symbols in a slide--12, 18, 24 (amount); type of change introduced in a single update--symbols removed, added, repositioned; extent of change in a single

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[1] Andrews, R. S., and Ringel, S. Certitude judgments and the accuracy of information assimilation in visual displays. U. S. Army Behavioral Science Research Laboratory Technical Research Note 145. May 1964.

update-- 2, 4, 6 symbols changed, and enhancement techniques--hard copy, single-cue coding, double-cue coding. A no-coding condition was also imposed to provide a base performance index. Measures of accuracy of assimilation and certitude about that accuracy were coordinate dependent variables.

The basic design of the experiment is shown schematically in Figure 1.

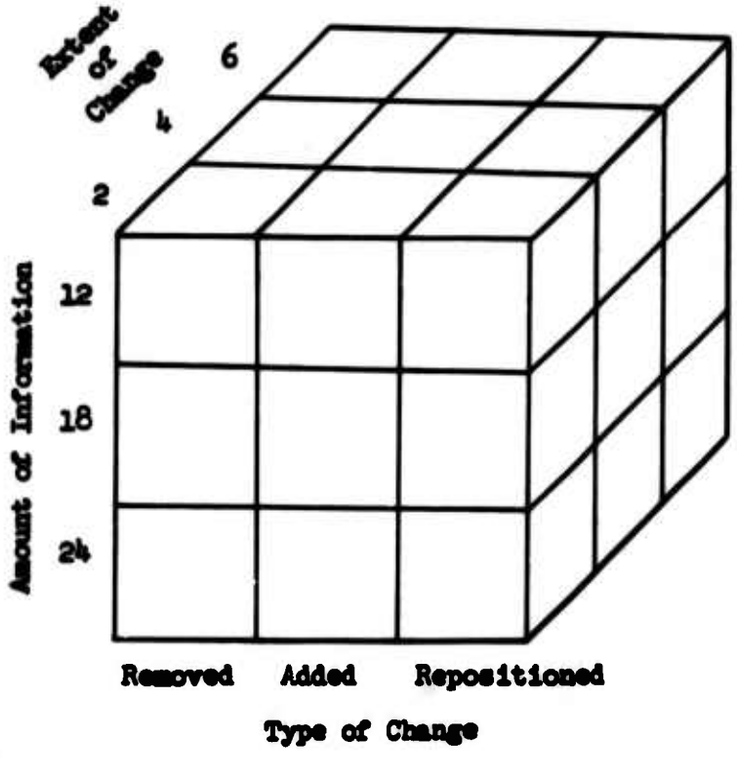

Figure 1. Schematic design of experiment for a single enhancement technique

There were four replicates of the basic design, one for each enhancement technique. Twelve subjects were randomly assigned to each replicate and each subject received all treatment combinations of amount by extent by type. Within each replicate, the twelve subjects were randomly divided into three groups of four subjects each. Groups differed only in order of presentation of type of change and the randomized sequence of slide

presentation within type of change. Thus, within each replicate each type of change was administered first, second, and third, and there were nine different random sequences of slides.

Subjects

Forty-eight military personnel of above average intelligence (General Technical Aptitude Area score[1] of 110 or higher) with normal or corrected normal visual acuity participated as subjects. Military sophistication or training, not being pertinent to performance in the experimental task, was not a requirement. Each subject participated for the 90 to 120 minutes required to complete a session.

Stimulus Presentation

Stimuli were in the form of 35mm negative transparencies depicting a number of military flag symbols positioned on a skeleton map. Each pair of slides was made up of a basic slide and an updated slide which differed from the basic slide only in the changes introduced in updating. Figures 2 and 3 show a pair of such slides. The illustrations differ from the slides used in the experiment only in that the projected image gave white symbols and lines on a dark background.

Positioning the symbols on the basic slides and selecting the symbols to change in updating were both done by a randomization process with only one restraint: There were four different military unit symbols--Infantry, Artillery, Air Defense, and Engineer--on each basic slide in the approximate proportions of 1/2, 1/4, 1/6, and 1/12, respectively. In no instance of the symbols "removed" condition were all of any particular type of unit removed.

Figure 4 shows the coding used for single-cue and double-cue updates. For the other enhancement technique, hard copy, a page print of the first slide was made available to the subject simultaneously with the uncoded updated slide. Uncoded symbols were identical to single cue except that there was no "arrow" for moved, no "N" for added, and no "broken line perimeter" for removed.

Subjects were seated directly in front of and 15 feet away from the screen on which the slides were rear projected with an image area approximately 7.6 feet by 5 feet. Ambient illumination was maintained at a level sufficient to reduce the possibility of after images, to provide light for the men to read and mark their answer sheets, and yet not high enough to interfere with easy viewing of the displayed material.

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[1] Based on the Verbal and Arithmetic Reasoning Tests of the Army Classification Battery.

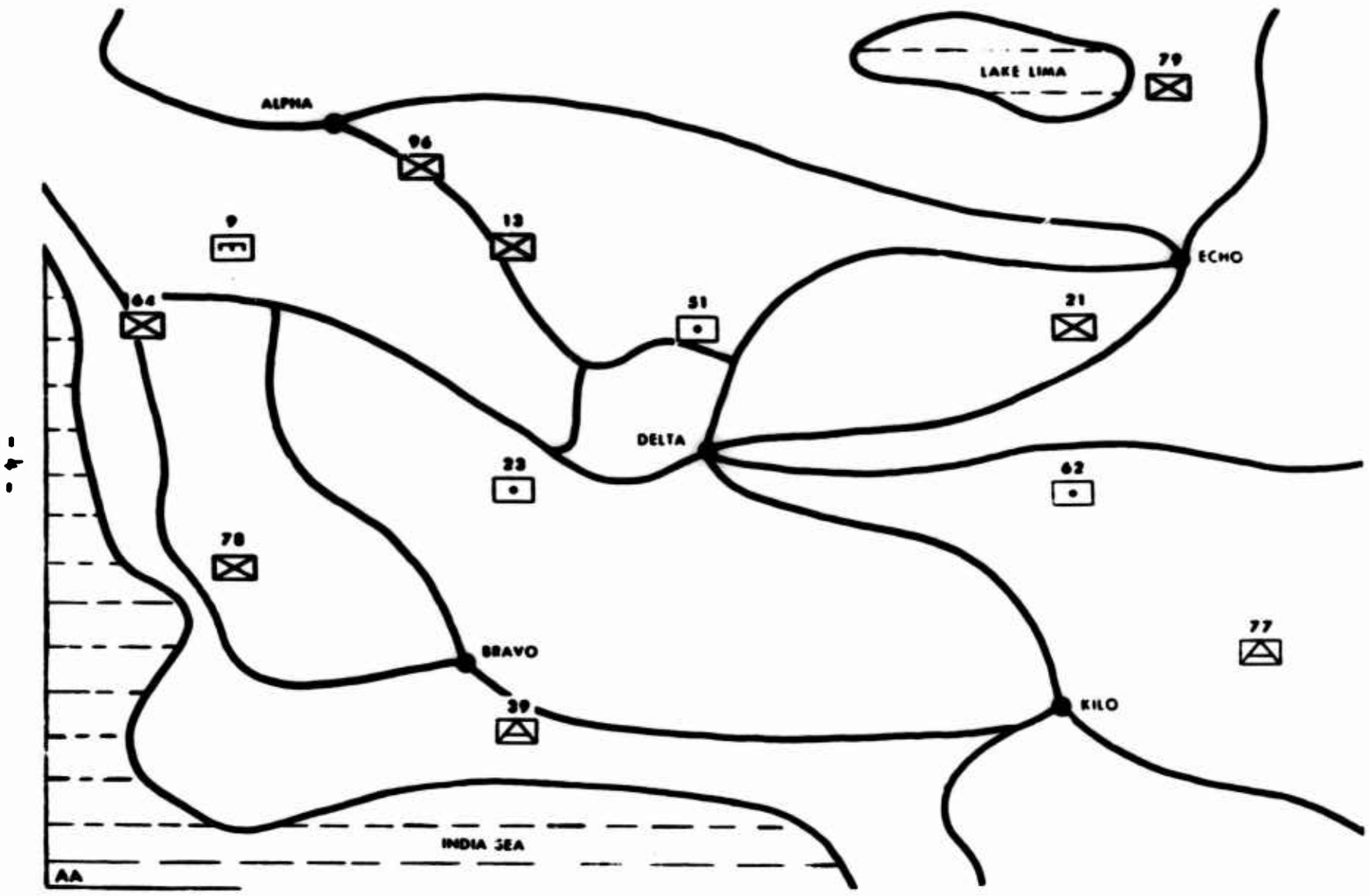

Figure 2. Basic slide with 12 symbols

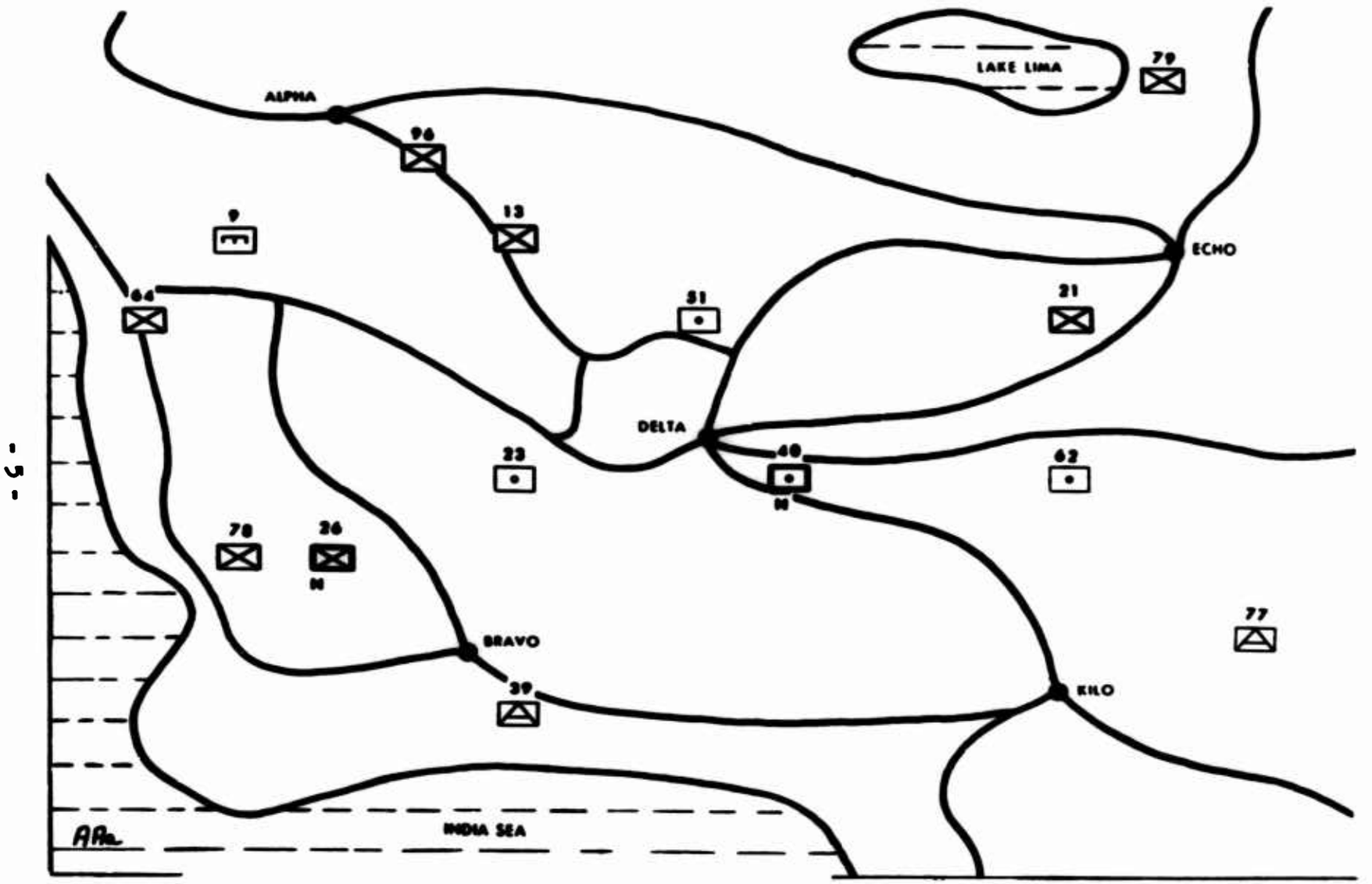

Figure 3. Updated slide with 2 "added" symbols

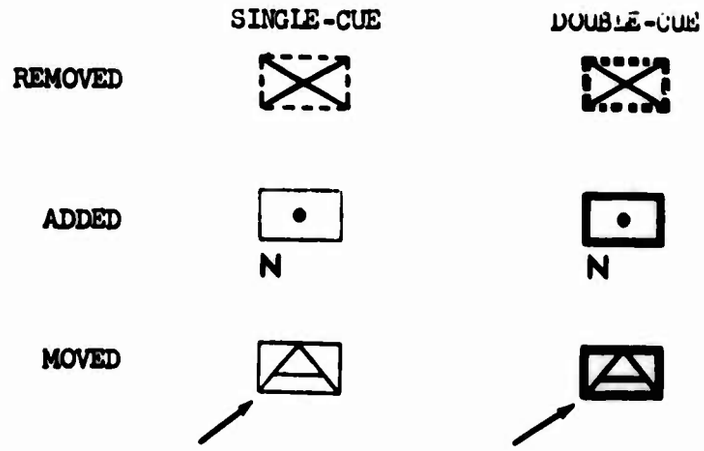

Figure 4. Examples of single-cue and double-cue coding

Procedures and Instructions

Before the start of a session, subjects were briefed on the nature of the experiment and their participation. The experimenter read the instructions aloud, while each man followed along on a printed copy. Two practice slide sets were presented and--after the experimenter had answered all questions and assured himself that the subjects understood their task--the experiment proper began.

Within each pair of slides, a basic slide was presented for 60 seconds; the updated slide (the same as basic slide with 2, 4, or 6 symbols added, removed, or repositioned) was then presented. Simultaneously with the showing of the updated slide, the subjects were given a question relating to "how many" of a particular type unit had been changed. Forty-five seconds were allowed for answering, after which a second question relating to "locations" of a specific change was given and another 45 seconds allowed for answering and continued viewing of the updated slide. Thus, the subjects had a total of 90 seconds' viewing time for the updated slide. The updated slide was then turned off, and the subject turned to his response sheet (replica of basic slide) and indicated all units which he thought had been changed as a result of the updating. These responses provided a measure of information assimilation. The subject had 60 seconds to complete his answer and indicate his certitude for that answer on the scale provided. The same procedure was followed until nine pairs of slides had been presented. Subjects were then permitted a five-minute break. This procedure was followed for each of the three type-of-change sequences within a session.

Dependent Variables

The major dependent variable considered was the certitude expressed by the subjects in the accuracy of their information assimilation. To indicate his certitude, a subject circled the phrase on the following scale which best described how certain or uncertain he felt in the accuracy of his response. Successive integers assigned to the eight categories of the continuum were the values used in the analyses.

Absolutely Uncertain	Very Uncertain	Moderately Uncertain	Slightly Uncertain	Slightly Certain	Moderately Certain	Very Certain	Absolutely Certain

The performance accuracy score was computed as follows:

$$\frac{\text{Number Right}}{\text{Number Right + Errors of Commission + Errors of Omission}} \times 100$$

An error of commission was made when the subject marked a symbol that had not been changed, an error of omission when he failed to mark a symbol that had been changed.

RESULTS

A summary of the analysis of variance performed on the certitude scores is shown in Table 1. All four main effects and three of the interactions were significant beyond the .001 level. Only one of the other effects achieved significance at or beyond the .05 level. These findings conform closely to those from the analysis of the accuracy data[1] in a prior study in which the identical variables and interactions were the only ones achieving statistical significance at or beyond the .05 level except for the accuracy by type of change by enhancement technique interaction which was not significant in the accuracy analysis. The relationships between mean certitude and mean accuracy for each of the main effects are plotted in Figures 5 through 8. It is apparent from these figures that the certitude-accuracy relationship typically approximates linearity except for enhancement technique for which the relationship departs appreciably from linearity (Figure 8).

[1] The accuracy data and analyses used for comparison purposes were extracted from a prior report (Vicino, F. L., Andrews, R. S., and Ringel, S. Conspicuity coding of updated symbolic information. U. S. Army Behavioral Science Research Laboratory Technical Research Note 152. May 1965) and are not presented in detail in the present publication.

Table 1

SUMMARY ANALYSIS OF VARIANCE FOR CERTITUDE

Source of Variation	Df	MS	F
Enhancement Technique (E)	3	179.51	11.83**
Subjects within Enhancement Sw(E)	44	15.18	
Type of Change (T)	2	173.53	32.98**
T x E	6	28.89	5.49**
T x Sw(E)	88	5.26	
Amount of Information (A)	2	95.13	41.67**
A x E	6	20.30	8.89**
A x Sw(E)	88	2.28	
A x T	4	.92	.61
A x T x E	12	2.82	1.88*
A x T x Sw(E)	176	1.50	
Extent of Change (C)	2	102.58	40.09
C x E	6	5.25	2.05
C x Sw(E)	88	2.56	
C x T	4	12.55	6.45**
C x T x E	12	6.91	3.55**
C x T x Sw(E)	176	1.94	
C x A	4	3.12	1.73
C x A x E	12	4.99	2.78**
C x A x Sw(E)	176	1.80	
C x A x T	8	3.50	1.92
C x A x T x E	24	2.38	1.30
C x A x T x Sw(E)	352	1.83	
TOTAL	1295		

*P <.05
**P <.001

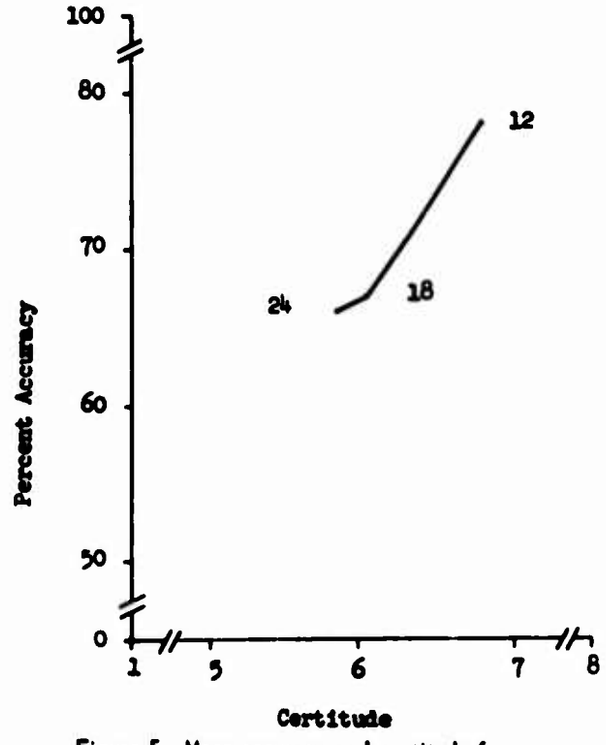

Figure 5. Mean accuracy and certitude for amount of information

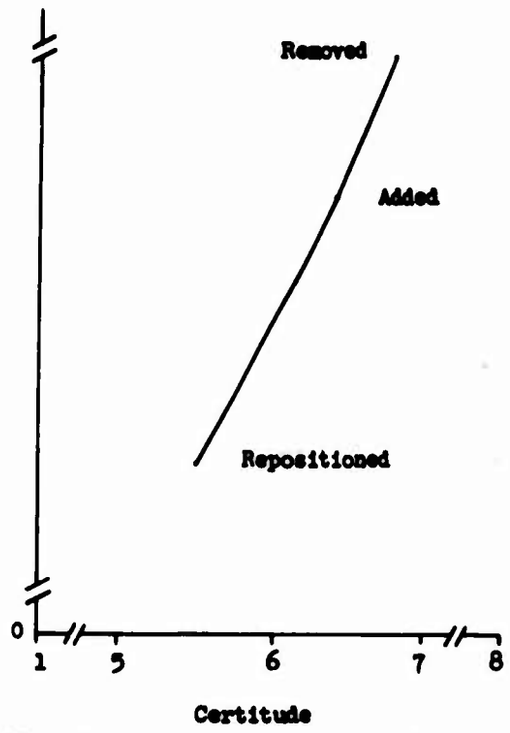

Figure 6. Mean accuracy and certitude for type of change

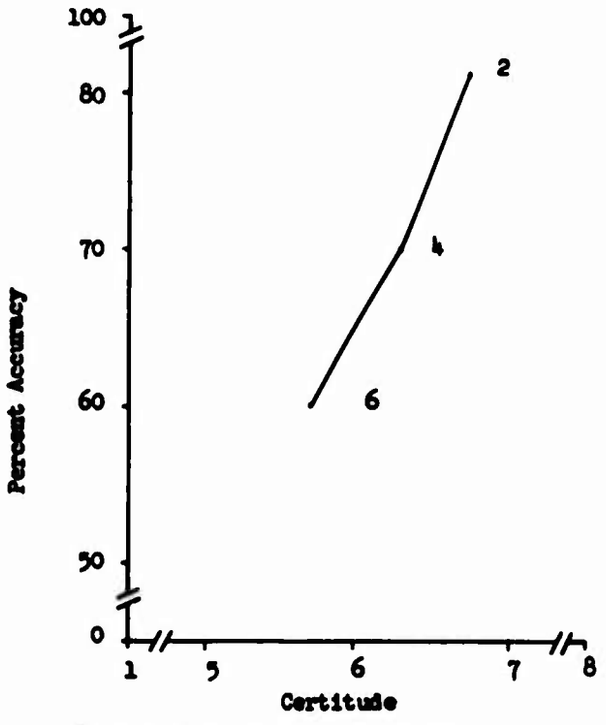

Figure 7. Mean accuracy and certitude for extent of change

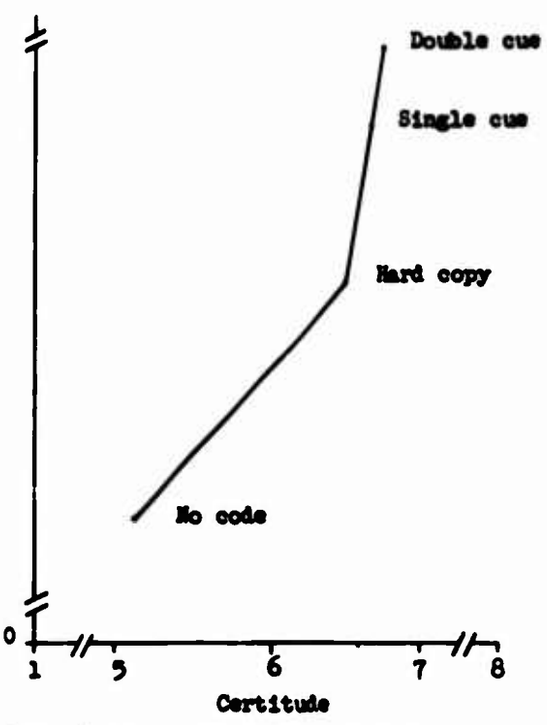

Figure 8. Mean accuracy and certitude for enhancement technique

Pursuing the similarities farther, the Newman-Keuls Studentized range test[2] was applied for testing differences between pairs of means within each of the main variables. The results are shown in Table 2. Only for enhancement technique did certitude and accuracy scores differ in terms of which pairs of means encompassed statistically significant differences. For all main effects, including enhancement technique, the rank orders of the means were identical. It is likely that the non-linearity of the certitude-accuracy relationship and the greater differences among enhancement techniques for accuracy means than for confidence means were in large part a function of the fact that these comparisons were between groups, i.e., each subject performed on only a single enhancement technique. It was to be expected that an individual's certitude estimates would be less precise in an absolute sense than in a relative sense. Thus, a constant error in terms of a subject's subjective certitude scale would affect between subject comparisons but not within subject comparisons.

Table 2

MEAN CERTITUDE FOR LEVELS WITHIN EACH MAIN VARIABLE

Variables	Condition Levels			
Enhancement Techniques	No Code	Hard Copy	Single Cue	Double Cue
	5.14	6.32	6.63	6.72
(Accuracy Score)	(55)	(68)	(78)	(85)
Type of Change	Removed	Added	Repositioned	
	6.79	6.41	5.55	
Amount of Information	12 Symbols	18 Symbols	24 Symbols	
	6.79	6.05	5.92	
Extent of Change	2 Symbols	4 Symbols	6 Symbols	
	6.74	6.24	5.77	

NOTE: Values connected by lines do not differ significantly at $P < .05$. Entries in parentheses are corresponding accuracy scores and appear only for main effects where confidence and accuracy differ in terms of significance of differences between pairs of means.

[2] Winer, B. J. Statistical Principles in Experimental Design. New York. McGraw-Hill, 1962.

Plotting the significant two-way interactions--type of change by enhancement, amount of information by enhancement, and extent by type of change helps clarify the nature of the interactions. Figure 9 shows differential certitude effects for type of change across enhancement techniques, with repositioning the major contributor. Since double-cue coding produced the highest accuracy for the symbols removed and symbols added conditions and was equivalent to the highest (hard copy) for the symbols repositioned condition, the relatively lower certitude level for the symbols repositioned condition may be attributable to a more realistic certitude estimate with double-cue coding.

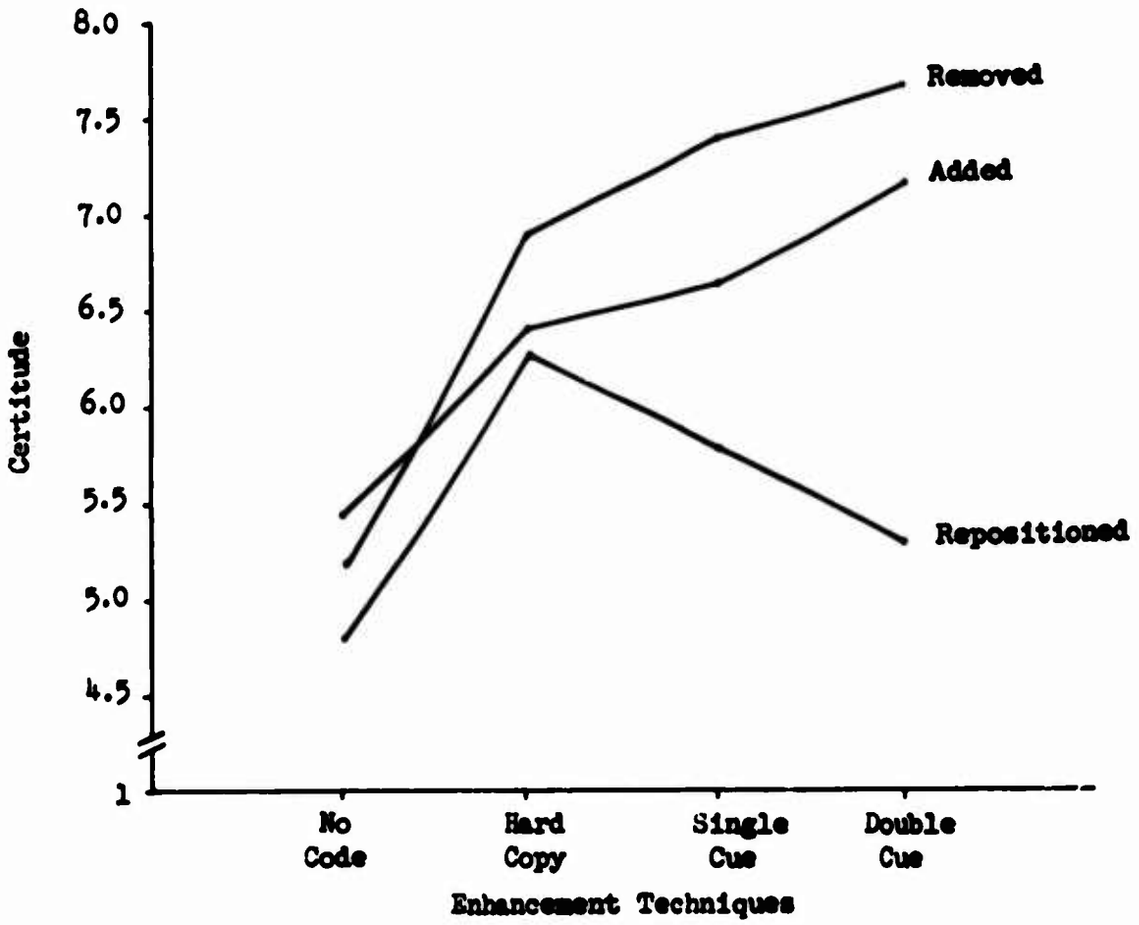

Figure 9. Mean certitude for type of change by enhancement technique

The shape of the functions plotted in Figure 10 for the amount of information by enhancement technique interaction are very similar to those for accuracy except that the rank order for enhancement technique on accuracy was double cue, single cue, hard copy, and no code at each amount level. The finding reported in Table 2 of no significant differences in confidence among hard copy, single-cue, and double-cue enhancement must be qualified in light of this amount by enhancement interaction, since hard copy was significantly different from the other two at the 24-amount level. Similarly, there was a differential change in certitude in going from the 18 to 24 amount level across enhancement technique, though there was no significant difference between the 18 to 24 amount levels over all enhancement techniques.

The final significant interaction, extent by type of change, is plotted in Figure 11. The certitude functions are virtually identical to those for accuracy. Thus, the finding of significant differences among extents of change as simple effects needs be tempered merely by the finding that these differences exist only for the added and repositioned type of change--not for symbols removed--and that differences among types of change do not hold between symbols removed and symbols added at the 2- and 4-extent of change levels.

The seemingly high correspondence between accuracy and certitude in terms of how these measures were affected by the variables of interest prompted a closer look at this relationship. Since the certitude estimates were of a qualitative nature not translatable into a metric directly comparable to the accuracy scores (percent right), correlation techniques were applied. Product moment correlations based on the 324 pairs of measures (accuracy and certitude) within each enhancement technique and the 1296 pairs of all enhancement techniques combined produced coefficients of .79 for double cue, .63 for single cue, .45 for hard copy, .30 for no code, and an overall correlation of .62. At least two inferences can be drawn from these data. The first is that improved enhancement techniques contribute not only to accuracy of information assimilation but also to the appropriateness of certitude estimates regarding assimilation performance. Second, despite the similarity of the effects the main variables had on accuracy and certitude, the relationship on an individual score basis over all conditions is not impressive since no more than approximately 36 percent of the variance in certitude estimates can be accounted for by accuracy variance.

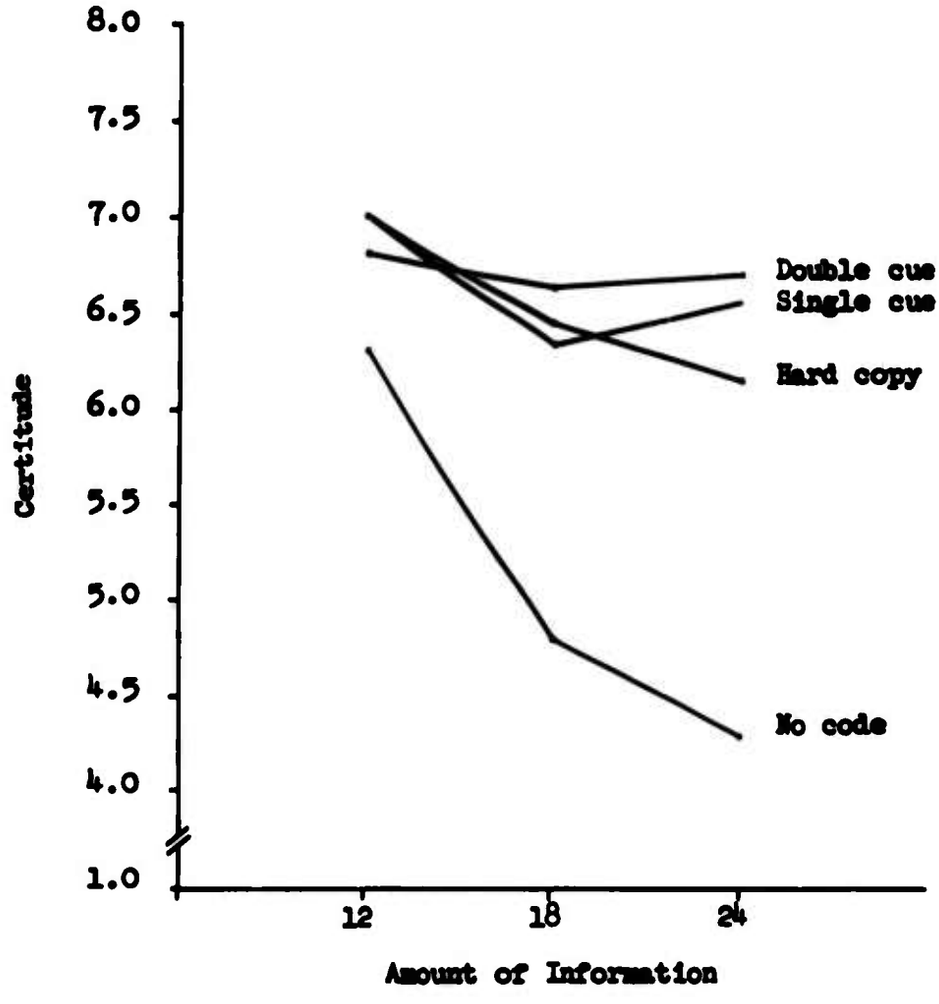

Figure 10. Mean certitude for amount of information by enhancement technique

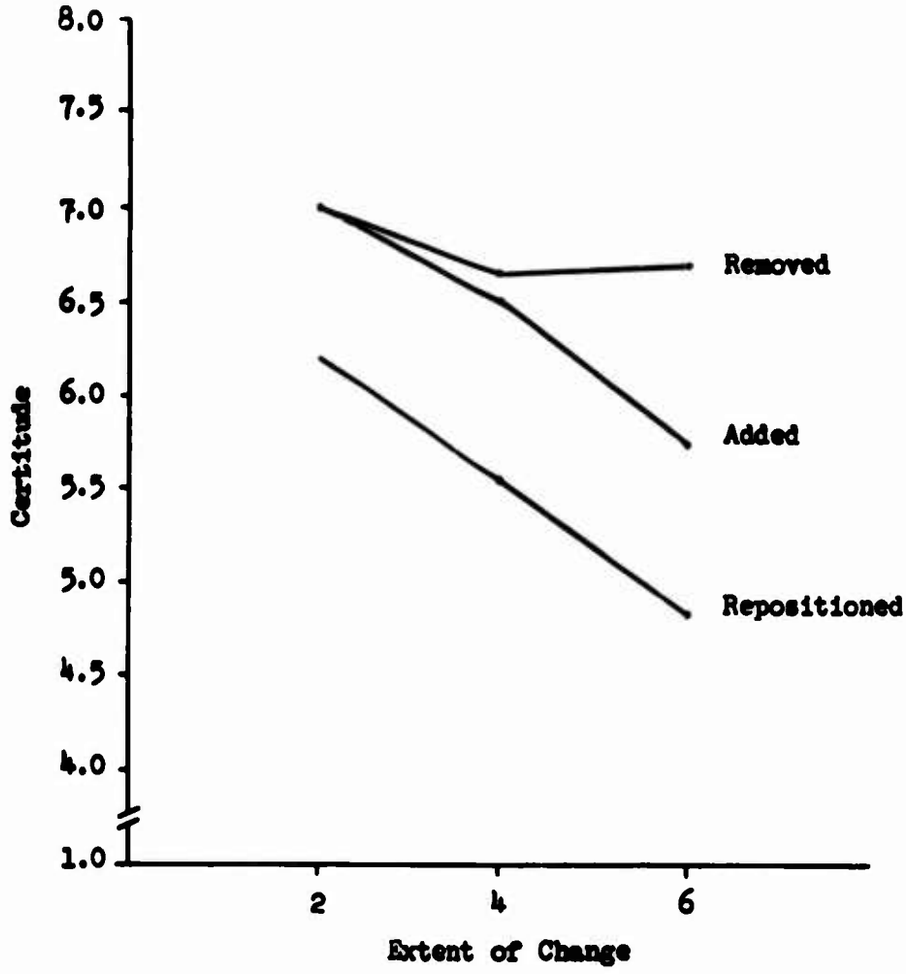

Figure 11. Mean certitude for extent of change by type of change

Because of the subjective nature of the certitude continuum, it was not possible to determine whether certitude estimates were typically higher or lower than warranted by the accuracy. Data can be adduced for both over- and under-estimation. Table 3 shows, for enhancement technique, what percent of the 100% correct responses had certitude estimates of "absolutely certain" associated with them and what percent had either "absolutely" of "very certain", as well as the converse, for example, what percent of responses rated "absolutely certain" proved to be 100% correct.

Table 3

CORRESPONDENCE BETWEEN ACCURACY AND CERTITUDE
BY ENHANCEMENT TECHNIQUE

Certitude Expressions	Enhancement Techniques			
	No Code	Hard Copy	Single Cue	Double Cue
Responses 100% right--estimated "absolutely certain" by subject	25%	62%	67%	71%
Responses 100% right--estimated "absolutely" or "very certain"	58	85	86	93
Responses estimated "absolutely certain"--100% right	33	62	89	94
Responses estimated "absolutely" or "very certain"--100% right	51	54	82	84

The figures in the first two rows can be viewed as evidence of under-estimation of performance and those in the last two rows as evidence of over-estimation, albeit tenuous. More important is the evidence supporting the notion that enhancement techniques which tend to improve accuracy of information assimilation also improve the relationship between accuracy and subjective estimates of accuracy. That the relative ease of the information assimilation task as a function of enhancement technique does affect certitude is further evidenced in Table 4. The mean percent right

associated with each certitude category, particularly the higher ones, differs considerably as a function of enhancement. Thus, the effective scale range for the no-code condition is compressed downward from the top relative to the double-cue and single-cue conditions. Typically, the 50 percent correct point falls between 4 and 5 on the scale (slightly uncertain and slightly certain).

Table 4

MEAN PERCENT RIGHT FOR EACH SCALE CATEGORY SEPARATELY BY ENHANCEMENT TECHNIQUE

Certitude categories	Enhancement Techniques			
	Double Cue	Single Cue	Hard Copy	No Code
8	98	96	83	76
7	88	87	76	79
6	78	76	63	63
5	61	44	54	56
4	45	70[a]	45	36
3	44	60	52	52
2	39	49	42	38
1	23	21	10	23

[a] Unusually high value attributable to the few (6) responses of which one was 100% and one 83% correct.

IMPLICATIONS OF THE FINDINGS

For information assimilation tasks of the type considered here, mean certitude functions appear to conform to the mean accuracy functions reasonably well, at least in terms of shape. Because of the different metrics, it was not feasible to determine quantitatively the degree of conformity or whether the certitude judgments were predominantly overestimates or underestimates. The conformity of means is a poor representation of the relationship between an individual's accuracy of assimilation and the degree of certitude he ascribes to his accuracy. Not only is the agreement over all conditions less than would be desired ($r = .62$); it also varies considerably as a function of enhancement technique, only double-cue coding showing a relationship such that more than 50 percent of the certitude variance can be accounted for by accuracy variance. Apparently, the less conspicuous the changes in the updated slides the less the subjects were aware that they were right when in fact they were and that they were not right when in fact they were not. Also, it is not surprising that people are more likely to be 100 percent correct when they say "absolutely certain" than they are to say "absolutely certain" when they are 100 percent right. The fact that these judgments concern an end category of the continuum, the literal meaning of the anchor terminology itself--and previous findings which frequently indicate conservatism in such judgments--would lead to this expectation.

The major efficacy of enhancement techniques is assumed to reside in reducing the difficulty of the task. Thus, a further degradation in the certitude-accuracy relationship within an enhancement might be produced if the other conditions--amount and extent of change--were extended beyond those of the present study in terms of making the task more difficult. Thus, making a task as manageable as possible by provision of the best possible enhancement aids is clearly advantageous.

The fact that the earlier findings of consistent accuracy of assimilation but declining certitude for increasing numbers of "symbols removed" were not sustained in the present study suggests subject differences and/or task factors as determinants of this relationship. Task realism and research designs calling for repeated measures would seem to be desirable controls for future research in this area.

Either the adjectival anchors on the certitude continuum assume somewhat different meanings for the subjects as a function of enhancement technique, or the accuracy of application varies as a function of enhancement technique. An adequate determination of the nature of these effects requires a continuum where a quantitative metric is explicitly associated with each category or subjects are allowed free response in a prescribed quantitative metric. Studies conducted subsequent to the present one have incorporated such procedures with apparent success.

Even with the inadequacies of the present certitude continuum, indications are that to the extent that feelings of certitude or confidence influence the timeliness and/or appropriateness of decision, discrepancies of the present magnitude between accuracy and certitude could frequently have a deleterious effect on the decision process.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
U.S. Army Behavioral Science Research Laboratory, OCRD
Washington, D. C.

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
RELATION OF CERTITUDE JUDGMENTS TO CHARACTERISTICS OF UPDATED SYMBOLIC INFORMATION

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)
Robert S. Andrews, Frank L. Vicino, and Seymour Ringel

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
April 1968	31	4

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. DA R&D PJ No. 2J024701A723	Technical Research Note 194
c. Command Systems	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d. e-11	

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Combat Dev Cmd, Fort Belvoir, Va. Army Materiel Cmd., Wash., D. C. Automatic Data Fld Sys Cmd., Ft Belvoir, Va

13. ABSTRACT

Technological advancements in military operations and stepped-up need for command tactical decisions consistent with rapid change and succession of events requires maximal effectiveness in the processing and use of military operations information. To this end, the Army is developing automated systems for receipt, processing, storage, retrieval, and display of different types and vast amounts of military data. As part of the requirements for research, a series of studies has been conducted by the COMMAND SYSTEMS Task in which a variety of display variables are systematically investigated in terms of their effects on information assimilation and decision making in a command and control setting. The present study explores the effects of type and number of updating change, amount of information presented, and selected enhancement techniques on confidence and on the relationship of confidence to accuracy of information assimilation. In the experiment, nine successive pairs of 35mm negative transparencies were viewed by 48 subjects. The first slide of a pair contained 12, 18, or 24 military flag symbols randomly positioned on a map. The second slide was identical to the first except that 2, 4, or 6 symbols had been added, removed, or repositioned. Subjects viewed both slides, then, after removal of the second slide, indicated on a paper print of the first slide all updates they had noted on the second. Performance was measured in terms of accuracy of assimilation (percentage score) and certitude expressed in that accuracy. For analysis, successive integer values of 1 - 8 were assigned to the eight certitude judgment categories ranging from absolutely uncertain at the lower end of the continuum to absolutely certain at the upper end. This experimental procedure was repeated for each of the three type-of-change sequences within a session--single-cue coding, double-cue coding, and hard copy as well as for a no-coding

DD FORM 1 NOV 65 1473 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

Unclassified
Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
*Automated command information processing systems *Information processing Information assimilation *Information presentation techniques *Display modalities Decision making *Certitude judgment						

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13. ABSTRACT continued

condition. Findings indicate: 1) The more effective the enhancement technique, the higher the certitude-accuracy relationship. With the best enhancement technique (double-cue coding), 64 percent of the certitude variance could be accounted for by accuracy variance; with the poorest (hard copy), only 20 percent. 2) Both over-certitude and under-certitude was evidenced, with over-certitude tending to increase with the less effective enhancement techniques. 3) Increase in either amount of information presented or amount of updating resulted in decline in both mean accuracy and mean certitude, the rate varying widely over the different enhancement techniques and over types of update. 4) Although effects of the main variables on accuracy and certitude were highly similar, the correspondence did not hold for individual performance scores. Findings suggest need to improve agreement between a man's performance in information assimilation and his judgment of that performance. To more adequately determine the nature of the effects of enhancement, certitude should be measured in the same quantitative metric (percent) as accuracy.

SUPPLEMENTARY

INFORMATION

AD-831 288 Army Behavioral Science Research Lab., Washington, D. C. Technical research note. Rept. no. BESRL-TRN-194 Apr 68	No Foreign without approval of Army Behavioral Science Research Lab., Attn: OCRD, Washington, D. C.	No limitation	USABSRL ltr, 31 Jan 69